**Note 35**

## The influence of Maurice Sizaire on piston engine design

The common 1906 belief that in piston engines a limit of 6 m/s (1,200 feet/minute) applied to the Mean Piston Speed [MPS = 2 x Stroke (S) x N RPM], because of inertial stresses (proportional to $MPS^2$) in the then-usual cast-iron pistons, was based on tests by the Automobile Club de France (ACF) of a wide variety of engines built up to that date (4). Changes in the piston material or its geometric proportions were not considered.

The consequence of a belief in a constant, limited, MPS can be seen by considering it in relation to the basic power equation:-

Power (P) proportional to [Brake Mean Effective Pressure (BMEP) x Swept Volume (V) x N]
where V = [Piston Area (PA) x S]
therefore P is proportional to [BMEP x PA x MPS].

In 1906 there was no discussion of how BMEP could be increased from existing levels, e.g. by raising Compression Ratio (R) above the range of 3 to 4 enforced to avoid detonation by the petrol of the day, because the influence on that parameter of fuel, inlet charge conditions and combustion chamber shape, etc, was unknown.

Therefore, taking BMEP for granted and then assuming a constant limiting value of MPS led the French organisers of the 1907 – 1908 Coupe de l'Auto Voiturette races to set only PA limits for power control. For a single-cylinder the maximum bore permitted was 100mm More generous PA was allowed for twins (+28%) and more again for fours (+69%), partly, perhaps, by perceptions of their respective lower efficiencies from higher area/volume ratios and more moving parts. More probably this generosity was *intended* to lead designers to smoother and more touring-useful multi-cylinder engines but, if so, it did not achieve its aim for several years.

Maurice Sizaire was the designer of the 1906 Coupe winner built by Sizaire et Naudin, which was 1 cylinder of Bore (B)/ S = 120mm/110 = 1.09 which had achieved an MPS of 7.3 m/s and Peak Power (PP)/ PA of 0.16 HP/$cm^2$. Not being a college-educated man – he had been a builder's draughtsman (361) – he had no respect for theoretical dogma on MPS. Instead he saw "Free Stroke" as an opportunity. He built in 1907 a 1 cylinder engine of 100mm/150 = 0.67 with *machined-steel pistons* which ran up to MPS = 12 m/s and produced 0.28 HP/$cm^2$, and this won the Coupe and also took 2nd place. In 1908 he went further still with a 1 cylinder engine 100mm/250 = 0.4 reaching 20 m/s and giving PP/PA = 0.53 HP/$cm^2$, again taking 1st and 2nd places in the Coupe (data from (259, 361); other details are given in Sub-Note A).

There *was* piston trouble in 1907. Maurice Sizaire admitted in 1964 (361) – 57 years after the event! – that the pistons had been machined too thinly and had to be changed during the race. This was done by driving each car into a wood alongside the long circuit, where it was an easy matter to fit new pistons to single cylinders having only 4 holding-down studs. Clearly, spares had been smuggled onto the cars in anticipation of a change, although it was against the rules. The 10 minutes time loss was explained to the stewards as drivers' calls of nature! However, this piston problem was *not* fundamental, as proved by the 1908 success at even higher MPS, noting that this race was 400 km long. Of course, the maximum MPS would not be used continually. The 1908 S & N level of 20 m/s (4,000 ft/min) *did* remain roughly the new limit for MPS for 6 decades afterwards, depending on race length and on Al-alloy pistons post-WW1 and whether Naturally-Aspirated or Pressure-Charged.

These 3 Sizaire engine types apparently were limited in RPM by their valve gear, since they ran at a constant Bore Speed [B x N] of 4 m/s. Therefore, [(PP/PA) x( B/S)] was fairly constant after allowing for R having been raised from 4.2 to 5 by 1908, worth nearly 9% of BMEP (see Sub-Note B). The reasoning on Bore Speed as a surrogate for Mean Valve Speed is given in Note 13 Part II.

The proof from these Sizaire engines that MPS was not then a limit under 20 m/s was quickly grasped by other Voiturette designers, including Michaux of Peugeot who even used B/S =0.25 in 1910.

The AC de la Sarthe clearly had these top-heavy Voiturettes in mind when setting the rules for a class in their projected 1911 race which restricted 4 cylinder B/S to 110mm/200 = 0.55 (V = 7,603 cc).

The new Peugeot racing car designer Ernest Henri began work to those rules but industry politics caused Peugeot to withdraw in 1911. However, the resultant Peugeot L76 EX1 then raced successfully in the 1912 Grand Prix de l'ACF and (with many other innovations) set a new standard for design, using MPS = nearly 15 m/s for that 1540 km race. The last previous Grand Prix winner in 1908, a Mercedes, had an MPS of just under 10 m/s for 770 km.

Frederick Lanchester

Frederick Lanchester in 1906 also had the same belief that RPM were limited by piston inertial stress and used Dimensional Analysis and piston geometry typical of the period (assuming that piston height would remain proportional to Bore) to suggest a "Rating Rule" in which the basic PP/PA was to be multiplied by **√**[B/S] to produce, he expected, a constant number for all engines (he offered later an alternative multiplier of **√**[(B/S)+ 0.3] (369).

Unfortunately for Lanchester's "Rating Rule" the Sizaire results disproved his theory shortly after it was published (see Sub-Note B). It is fair to say that he had not envisaged the grotesque engines which were developed for Voiturette racing.

The RAC Rating Rule

Also in 1906, the Royal Automobile Club (RAC) adopted a production engine piston area Rating Rule, slightly altered from a proposal by Prof. Dugald Clerk, which was equivalent to a PP/PA of just over ½ HP per square inch (0.079 $HP/cm^2$). HM Government accepted this RAC Formula, which was

$$PP = [0.4 \times \text{No. of cylinders} \times (B \text{ inches})^2]$$

for taxation purposes (on the principle that "people should pay for power"!) and held to it doggedly until 1947 in the teeth of evidence that the original averages used in the formula of MPS = 1,000 feet/minute (5.08 m/s) and BMEP = 67.2 psi (4.64 Bar) were being steadily left behind during 40 years of development of UK series-production engines. A pre-WW2-designed "bread & butter" example of 1947, the Morris "Ten" RAC HP having B/S = 63.5mm (2.5inches)/ 90 = 0.7 (V = 1,140 cc) ran at 2,700 ft/min (13.8 m/s)(+170%) with a BMEP of 92 psi (6.35 Bar)(+37%) to produce 37 HP @ 4,600 RPM.

In 1947, with the intention of inducing manufacturers to build engines more suitable for export markets, HMG then switched to a flat rate tax, irrespective of power. The first engine designed taking note of the new tax rule was the 1947 Standard "Vanguard" with B/S = 85mm/92 = 0.92 (V = 2,088 cc). This ran at 2,400 ft/min (12.3 m/s) and BMEP of 106 psi (7.29 Bar) to give 68 HP @ 4,000 RPM.

In 1947 an MPS of 2,500 ft/min (13 m/s) was considered a sound figure for a long-life production engine, where 4,000 ft/min (20 m/s) would be acceptable for a short-life Naturally-Aspirated pure-racing unit, both types using Al-alloy pistons.

Sub-Note A

Sizaire et Naudin Voiturette engines

Data sources (259,361).

| Date | No. Cyl. | Bore (B) / Stroke (S) mm | Swept Volume (V) cc | Compression Ratio (R) | Peak Power (PP)* HP | @ RPM |
|---|---|---|---|---|---|---|
| 1906 | 1 | 120 / 110 =1.09 | 1,244 | 4.2 | 18 | 2,000 |
| 1907 | 1 | 100 / 150 = 0.67 | 1,178 | 4.5 | 22 | 2,400 |
| 1908 | 1 | 100 / 250 = 0.4 | 1,963 | 5 | 42 | 2,400 |

*While listed as "Peak Power" the figures quoted are probably "Rated Power" at "Rated RPM", short of the true top of the power curve for mechanical reasons, which was typical in the early years.

The 1908 S & N engine is shown on Figs. SO3A and SO3B in "Significant Other" engines.

Sub-Note B

Sizaire et Naudin data compared with Lanchester's proposed Rating Rules

| Date | PP/PA HP/cm² | Lanchester's Rating proposals: $\frac{PP}{PA} \times \sqrt{\left(\frac{B}{S}\right)}$ | Lanchester's Rating proposals: $\frac{PP}{PA} \times \sqrt{\left(\frac{B}{S} + 0.3\right)}$ | $\frac{PP}{PA} \times \left(\frac{B}{S}\right)$ |
|---|---|---|---|---|
| 1906 | 0.16<br>Datum | 0.167<br>Datum | 0.189<br>Datum | 0.175<br>Datum |
| 1907 | 0.28<br>x 1.75 | 0.229<br>x 1.37 | 0.275<br>x 1.46 | 0.187 ÷ 1.035*<br>= 0.18<br>x 1.03 |
| 1908 | 0.53<br>x 3.31 | 0.335<br>x 2.00 | 0.443<br>x 2.34 | 0.212 ÷ 1.087*<br>= 0.195<br>x 1.11 |

*Adjusted by Air Standard Efficiency = $\left(1 - \frac{1}{R^{0.4}}\right)$ to value of R = 4.2 as for 1906.

"*Corrected* Mean Piston Speed"

Since PP is proportional to BMEP x PA x MPS, *if* Lanchester's basic proposal of

(PP/PA) x **√**(B/S) = constant was correct, then

BMEP x [**√**(B/S) x MPS] would also be constant.

Although Lanchester himself did not identify this conclusion, others have done so subsequently and called [**√**(B/S) x MPS] "*Corrected* Mean Piston Speed".

As shown above from the Sizaire et Naudin data produced in contemporary circumstances, the basic Lanchester idea, i.e., the adjustment of (PP/PA) by **√**(B/S) *did not yield a constant.* The conception of "*Corrected* Mean Piston Speed" is therefore unsound. It also has an implicit assumption that Piston Height is proportional to Bore and this has not been the case since WW1. This subject is discussed in detail in Note 13 Part I.